Postharvest Biology and Technology 107 (2015) 43–54

Contents lists available at ScienceDirect

Postharvest Biology and Technology

journal homepage: www.elsevier.com/locate/postharvbio

Correlations between subjective quality and physicochemical attributes of fresh fruits and vegetables

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ARTICLE INFO

Article history:
Received 9 November 2014
Received in revised form 30 April 2015
Accepted 3 May 2015
Available online 19 May 2015

Keywords:
Quality rating charts
Color
Texture
Weight loss
Anthocyanins
Chlorophyll

ABSTRACT

Color charts and rating scales have been developed for several fresh fruits and vegetables (FFVs) but limited information is available regarding the correlation between subjective evaluations and physicochemical attributes. The objective of this work was to correlate subjective quality data with quantitative analytical data collected for several fruits exposed to different environmental conditions. Avocados, blueberries, peppers, strawberries and tomatoes were exposed to a range of different temperatures and humidity conditions for varied periods of time, and quality evaluated using both rating scales and physicochemical analysis. The strength of the relationship between variables was measured using the Pearson correlation coefficient (r) and the coefficient of determination (r^2) and, the significance of the relationship was expressed by probability levels ($p = 0.05$). Overall, there was a significant correlation between most of the subjective quality attributes evaluated and the physicochemical analysis performed. Subjective color was significantly correlated with hue angle for all fruits evaluated except for blueberries for which subjective color had a stronger correlation with L^* values. Correlations between subjective color and anthocyanins, ascorbic acid or chlorophyll contents were also significant. Shriveling or stem freshness was strongly correlated with weight loss whereas subjective firmness was significantly correlated with instrumental texture. Results from this work showed that subjective quality evaluations using rating scales can be a reliable and simple method to estimate changes in color, softening, water loss, and ultimately changes in specific chemical components when FFVs are exposed to different environmental conditions. A color chart is proposed for the visual evaluation of strawberry quality.

1. Introduction

Visual appearance of fresh fruits and vegetables (FFVs) has the greatest impact on retailers buying decisions and on consumer choices and purchases. Attributes such as appearance, freshness and color are considered the foremost criteria used to evaluate the immediate quality of FFVs (Clydesdale, 1991; Mitcham et al., 1996; Barrett et al., 2010). As a result, they are used as quality indicators throughout the supply chain, from the farm to the consumer, and ultimately determine product acceptance or rejection. Texture, taste and aroma are also important sensory attributes but are mostly related with subsequent purchases (Clydesdale, 1991; Barrett et al., 2010). Nutrient content is not visible or touchable, and therefore is often disregarded as a quality attribute when it comes to food choices and purchase decisions. However, FFVs are important contributors to a well-balanced diet and to human wellbeing as they supply important macronutrients, such as carbohydrates and fiber, and micronutrients such as vitamins and minerals as well as polyphenols.

Subjective quality evaluations are often used to rate the appearance, texture and flavor of FFVs and, unlike formal sensory panels, these are usually performed by trained individuals but not on a sensory panel setting (e.g., quality control, and to estimate ripeness stage and maturity at harvest). Although these evaluations are criticized by some as being inexact, in the absence of formal analytical or affective sensory panels they are valuable to quality control, and to determine the ripeness stage or the end of shelf life of FFVs. In addition, they are faster, easier and less expensive than sensory panels or instrumental measurements which may require extensive training and complex logistics, or expensive equipment (Mitcham et al., 1996; Barrett et al., 2010). Consequently, many researchers frequently use somewhat quantitative scoring systems either alone or combined with drawings or photographs to evaluate the sensory quality of FFVs. For example, Kader and Cantwell (2006) developed several color charts along with rating scales and descriptors for physical damage of produce.

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http://dx.doi.org/10.1016/j.postharvbio.2015.05.001
0925-5214/

White et al. (2005) developed a color chart to describe skin color and avocado ripening. Our group also have developed a system that uses scores and descriptors to rate individual sensory quality attributes of various fruits and vegetables (Laurin et al., 2003; Nunes et al., 2003a,b,c; Nunes et al., 2004, 2006, 2007, 2011, 2012, 2013; Proulx et al., 2005; Nunes and Emond, 2007; Nunes, 2008; Proulx et al., 2010; Chilson et al., 2011). In the produce industry, color charts are also frequently used to assess the stage of ripeness (e.g., banana, tomato and avocado color charts) or to grade (e.g., size, color, and defects) or even to decide if a load of produce should be accepted or rejected based on visual inspection.

Many color charts and rating scales have been developed for several types of produce, and various studies have shown that correlations exist between sensory and physical and/or chemical attributes of FFVs (Ressureccion and Shewfelt, 1985; Maul et al., 2000,b; Harker et al., 2002a,b; Safner et al., 2008; Gunness et al., 2009; Pace et al., 2011; Corollaro et al., 2014). For example, firmness and color of tomatoes were highly correlated with sensory attributes (Ressureccion and Shewfelt, 1985) whereas perceived sweetness or sourness was correlated with specific volatile compounds (Maul et al., 2000). Pace et al., (2011) reported a significant correlation between b^*, chroma, pH, titratable acidity and appearance of fresh-cut nectarines. In apples, titratable acidity was suggested to be a good predictor of acid taste (Harker et al., 2002a,b) and texture analysis correlated well with sensory perception of apple texture (Harker et al., 2002a,b; Corollaro et al., 2014). However, these studies used consumer or trained sensory panels and to our knowledge there is a lack of published studies showing that subjective quality data collected by trained individuals (not in a sensory panel setting) can also be, in the absence of formal trained sensory panel, a reliable way the determined changes in the overall quality of FFVs. The objectives of this work were to: (1) correlate subjective quality data, such as color, firmness and shriveling, with quantitative analytical data collected for different FFVs, and to show that in the absence of a formal sensory panel the use of color charts and rating scales can be used by trained individuals as an accurate way of determining changes in overall quality of FFVs; and (2) give an example of a unique color chart designed for the evaluation of visual quality of strawberry based on correlations between individual subjective quality characteristics and physicochemical attributes, and that was validated in research and commercial settings.

2. Material and methods

2.1. Sampling

Fresh fruits and vegetables were harvested twice from commercial operations in Florida and transported to the laboratory within minimal delay after harvest (i.e., 1 to 6 h, depending on the distance between the field and the laboratory) (Tables 1 and 2). All FFVs were harvested at the commercial maturity stage, and cluster tomatoes were harvested from a greenhouse at the light-red stage. Upon arrival to the laboratory, FFVs were visually selected for uniformity of color/ripeness stage, size and freedom of defects.

Sample sizes were chosen based on the size and variability within each commodity (i.e., the smaller the size of the fruit the larger the number of fruits per replicates). Thus, three avocados, three peppers, two clusters of three tomatoes each, and three replicated samples of 15 or 20 strawberries and blueberries each, respectively, were used for initial subjective quality evaluation, and for instrumental color and texture analysis, and immediately frozen to be later used for chemical compositional analysis. A total of 20 avocados or 20 peppers (three fruit per RH), and 15 clusters of three tomatoes each (3 clusters per RH), and a total of 15 clamshells (3 clamshells per RH) containing 15 or 20 strawberries or blueberries, respectively, were distributed among the five RH-controlled rooms and reused daily or every two days for non-destructive quality evaluations (i.e., subjective quality evaluations and weight loss). For destructive quality evaluations (i.e., texture analysis and chemical analysis) and for non-destructive evaluations that required manipulation of the fruit to an extent that could cause minor bruising (i.e., instrumental color) 165 avocados or peppers (33 fruits per RH), and 110 clusters of three tomatoes each (22 clusters per RH), and 120 or 135 clamshells (24 clamshells per RH; 27 clamshells per RH, respectively) containing 20 or 15 blueberries and strawberries each, respectively were distributed among the five RH-controlled rooms. However, every day three clamshells of these strawberries or every two days, three of these avocados or peppers, and two clusters or tomatoes, and three clamshells of these blueberries were removed from their respective RH and immediately frozen, to be later used for chemical compositional analysis. Avocados were stored for 20 d, blueberries were stored for 16 d, and peppers and tomatoes were stored for 22 days and quality evaluated every two days. Strawberries were stored for nine days and quality evaluated every day (Table 2). For temperature treatments the experimental setup was similar to that used for RH treatments except that only avocados, strawberries and tomatoes were used in this part of the experiments (Table 1). Since all non-destructive quality analysis (i.e., subjective quality evaluations and weight) were assessed using always the same FFVs samples, those were conducted within approximately 30 min after the products were removed from storage, to minimize temperature fluctuations that could affect the quality.

2.2. Storage conditions

Storage conditions (i.e., temperature and relative humidity treatments) and experimental setup used in this study were similar to those previously described in detail by Nunes et al.

Table 1
Optimum storage conditions, cultivar, harvest location and date, and storage conditions during the temperature experiments.

Commodity	Optimum temperature (°C)	Optimum RH (%)	Cultivar	Origin	Harvest date	Storage duration (d)[a]
Avocados	5–12[b]	85–95[b]	'Choquette'	Homestead, Florida	October 1, 2008	22
			'Choquette'	Homestead, Florida	November 19, 2009	22
Strawberries	0[c]	90–95[c]	'Albion'	Floral City, Florida	December 12, 2008	10
			'Albion'	Floral City, Florida	March 9, 2009	10
Tomatoes	7–13[d]	90–95[d]	'Success'	Wellborn, Florida	January 15, 2009	22
			'Success'	Welborn, Florida	February 24, 2008	22

Storage conditions: (A) 1.8 ± 0.8 °C; (B) 5.2 ± 0.2 °C; (C) 10.6 ± 0.6 °C; (D) 15.2 ± 0.4 °C; (E) 20.2 ± 0.2 °C; ≈90% RH in all five temperature-RH controlled chambers.
[a] In some cases the experiments were terminated before the end of the storage period, at the time when at least one of the visual quality attributes evaluated reached the maximum acceptable (rating of 3).
[b] Woolf et al. (2014); evaluated every two days.
[c] Mitcham (2014); evaluated every day.
[d] Sargent and Moretti (2014); light red greenhouse-grown tomatoes; evaluated every two days.